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2 **Daily distribution of macronutrient intakes of professional**
3 **soccer players from the English Premier League**

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37 **Running head:** Distribution of macronutrient intake

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Abstract

The daily distribution of macronutrient intake can modulate aspects of training adaptations, performance and recovery. We therefore assessed the daily distribution of macronutrient intake (as assessed using food diaries supported by the remote food photographic method and 24 h recalls) of professional soccer players ($n=6$) of the English Premier League during a 7-day period consisting of two match days and five training days. On match days, average carbohydrate (CHO) content of the pre-match ($<1.5 \text{ g}\cdot\text{kg}^{-1}$ body mass) and post-match ($1 \text{ g}\cdot\text{kg}^{-1}$ body mass) meals (in recovery from an evening kick-off) were similar ($P>0.05$) though such intakes were lower than contemporary guidelines considered optimal for pre-match CHO intake and post-match recovery. On training days, we observed a skewed and hierarchical approach ($P<0.05$ for all comparisons) to protein feeding such that dinner ($0.8 \text{ g}\cdot\text{kg}^{-1}$)>lunch ($0.6 \text{ g}\cdot\text{kg}^{-1}$)>breakfast ($0.3 \text{ g}\cdot\text{kg}^{-1}$)>evening snacks ($0.1 \text{ g}\cdot\text{kg}^{-1}$). We conclude players may benefit from consuming greater amounts of CHO in both the pre-match and post-match meals so as to increase CHO availability and maximize rates of muscle glycogen re-synthesis, respectively. Furthermore, attention should also be given to ensuring even daily distribution of protein intake so as to potentially promote components of training adaptation.

Keywords: glycogen, protein, carbohydrate, soccer,

76 **Introduction**

77 The elite professional soccer player will typically
78 compete in two games per week as well as partake in three to
79 five daily training sessions (Malone et al., 2014; Morgans et al.,
80 2015; Anderson et al., 2015). As such, the fundamental goal of
81 the sport nutritionist is to ensure sufficient energy intake in
82 order to promote match day physical performance and recovery
83 (Burke et al., 2011). In relation to professional players of the
84 English Premier League (EPL), we recently observed (in a
85 companion paper) self reported mean daily carbohydrate
86 (CHO) intakes of 4.2 and 6.4 g.kg⁻¹ body mass on training days
87 and match days, respectively (Anderson et al., 2017). On this
88 basis, we therefore suggested that elite players potentially
89 under-consume CHO when compared with those guidelines
90 that are considered optimal to promote muscle glycogen
91 storage (Burke et al., 2011).

92 Nonetheless, in order to provide more informative
93 dietary guidelines (as opposed to total daily energy intake *per*
94 *se*), there is also the definitive need to quantify the daily
95 “distribution” of energy and macronutrient intakes. Such a
96 rationale is well documented for CHO given the relevance of
97 both timing and absolute CHO intake in relation to promoting
98 pre-match loading and post-match muscle glycogen re-
99 synthesis (Ivy et al., 1988a; Ivy et al., 1988b). To the authors’
100 knowledge, however, the daily distribution of CHO intake on

101 both training and match days in elite level soccer players has
102 not been reported.

103 In contrast to our previous observations of CHO
104 periodization between training and match days (Anderson et
105 al., 2017), we observed consistent daily protein intakes (e.g.
106 200 g), the magnitude of which was higher than previously
107 reported in the literature (Maughan, 1997; Bettonviel et al.,
108 2016; Gillen et al., 2016). Similar to daily CHO intakes,
109 however, there is also a requirement to quantify daily
110 distribution of protein intakes (Areta et al., 2013; Mamerow et
111 al., 2014). Indeed, these latter authors demonstrated that the
112 timing and even distribution of daily protein doses may have a
113 more influential role in modulating muscle protein synthesis
114 when compared with the absolute dose of protein intake *per se*,
115 an effect that is evident in response to both feeding alone
116 (Mamerow et al., 2014) and post-exercise feeding (Areta et al.,
117 2013). Such skewed approaches to protein feeding have been
118 previously observed in elite youth UK soccer players
119 (Naughton et al., 2016), adult soccer players of the Dutch
120 league (Bettonviel et al., 2016) and a mixed sex cohort of
121 multisport Dutch athletes (Gillen et al. 2016). However, given
122 that we observed higher absolute daily protein intakes
123 (Anderson et al., 2017) compared with all of the
124 aforementioned studies, there is also a need to further

125 understand the habitual protein feeding patterns in adult
126 professional UK soccer players.

127 Accordingly, the aim of the present study was to
128 therefore quantify the daily distribution of energy and
129 macronutrient intakes of professional soccer players of the
130 EPL. Importantly, we provide distribution data related to both
131 training and match days with practical applications therefore
132 related to promoting training adaptations and match day
133 performance. For analysis of total daily energy intake, daily
134 energy expenditure and training and match load of this cohort,
135 the reader is directed to a previous companion paper (Anderson
136 et al., 2017).

137

138 **Methods**

139 **Participants**

140 Six male professional soccer players from an EPL first
141 team squad (mean \pm SD; age 27 ± 3 years, body mass $80.5 \pm$
142 8.7 kg, height 180 ± 7 cm, body fat 11.9 ± 1.2 %, fat mass $9.2 \pm$
143 1.6 kg, lean mass 65.0 ± 6.7 kg) volunteered to take part in the
144 study. Players with different positions on the field took part in
145 the study and included 1 wide defender, 1 central defender, 2
146 central midfielders (1 defending and 1 attacking), 1 wide
147 midfielder and 1 center forward. All six players who took part
148 in the study have represented their respective countries at
149 national level. All players remained injury free for the duration

150 of the study. The study was conducted according to the
151 Declaration of Helsinki and was approved by the University
152 Ethics Committee of Liverpool John Moores University.

153

154 **Study Design**

155 Data collection was conducted during the EPL 2015-
156 2016 in-season in the month of November. Players continued
157 with their normal in-season training that was prescribed by the
158 club's coaching staff and were available to perform in two
159 competitive games on days 2 and 5 during data collection.
160 During data collection, game 1 kicked off at 20:05 hours and
161 game 2 kicked off at 16:15 hours, both being home fixtures in
162 European and domestic league competitions, respectively.
163 Before the study commenced all players underwent a whole
164 body fan beam Dual-energy X-ray absorptiometry (DXA)
165 measurement scan (Hologic QDR Series, Discovery A,
166 Bedford, MA, USA) in order to obtain body composition, in
167 accordance with the procedures described by Nana et al.
168 (2015).

169

170 **Dietary Intake**

171 Self reported EI was assessed from 7-day food diaries
172 for all players and reported in kilocalories (kcal) and
173 kilocalories per kilogram of lean body mass (kcal/kg LBM).
174 Macronutrient intakes were also analysed and reported in

grams (g) and grams per kilogram of body mass ($\text{g}\cdot\text{kg}^{-1}$). The period of 7 days is considered to provide reasonably accurate estimations of habitual energy and nutrient consumptions whilst reducing variability in coding error (Braakhuis et al., 2003). On the day prior to data collection, food diaries were explained to players by the lead researcher and an initial dietary habits questionnaire (24 h food recall) was also performed. These questionnaires were used to establish habitual eating patterns and subsequently allow follow up analysis of food diaries. Additionally, they helped to retrieve any potential information that players' may have missed on their food diary input. In addition, EI was also cross referenced from the remote food photographic method (RFPM) in order to have a better understanding of portion size and/ or retrieve any information that players' may have missed on their food diary input. This type of method has been shown to accurately measure the EI of free-living individuals (Martin et al., 2009). To further enhance reliability, and ensure that players missed no food or drink consumption, food diaries and RFPM were reviewed and cross checked using a 24-hour recall by the lead researcher after one day of entries (Thompson & Subar, 2008). As such, the lead researcher used these three sources of energy (i.e. food diaries, 24 h recall and RFPM) intake data in combination to collectively estimate daily energy and macronutrient intake / distribution. To obtain energy and

macronutrient composition, the Nutritics professional diet analysis software (Nutritics Ltd, Ireland) was used. Energy and macronutrient intake was further assessed in relation to timing of ingestion. Meals on training days were split into breakfast, morning snack, lunch, afternoon snack, dinner and evening snack. Time and type of consumption was used to distinguish between meals; breakfast (main meal consumed between 6-9.30am), morning snack (foods consumed between the breakfast main meal and the lunch), lunch (main meal consumed between 11.30-1.30pm), afternoon snack (foods consumed between lunch and dinner), dinner (main meal consumed between 5-8pm), and evening snack (foods consumed after dinner and prior to sleep).

Meals on match days were split into pre-match meal (PMM), pre-match snack (PMS), during match (DM), post-match (PM) and post-match recovery meal (PMRM). Timing of events was used to distinguish between meals on match days; PMM (main meal consumed 3 hours prior to kick off), PMS (foods consumed between the PMM and entering the changing rooms after the cessation of the warm up), DM (foods consumed from when the players entered the changing rooms after the warm up until the final whistle or since they were substituted), PM (foods consumed in the changing rooms after the match), PMRM (main meal consumed <3 hours after the end of the match).

225

226 **Inter-Researcher Reliability of the Methods**

227 To assess inter-researcher reliability, author one, author two
228 and an independent researcher (not included on the authorship)
229 individually assessed energy intake data for one day of one
230 player selected at random. No significant difference was
231 observed (as determined by one-way ANOVA) between
232 researchers for energy (P=0.95), CHO (P=0.99), protein
233 (P=0.95) or fat (P=0.80) intake. Daily totals for researchers 1,
234 2 and 3 were as follows: energy intake = 3174, 3044 and 3013
235 kcal; CHO = 347, 353 and 332 g; protein = 208, 201, and 194
236 g and fat = 106, 92 and 101 g, respectively.

237

238 **Statistical Analysis**

239 All data are presented as the mean \pm standard deviation
240 (SD). Meal distribution data was using linear mixed models
241 with meal as the fixed factor. A random intercept was set for
242 each individual player. When there was a significant ($P < 0.05$)
243 effect of the fixed factor, Tukey post-hoc pairwise comparisons
244 were performed to identify which categories of the factor
245 differed. This whole analysis was performed separately for
246 training and match days. In the match day's analysis, a fixed
247 factor for day was also included to compare energy intake and
248 distribution of the two different match days. In all the analyses,
249 statistical significance was set at $P < 0.05$. The statistical

analysis was carried out with R, version 3.3.1.

Results

Energy and Macronutrient Distribution Across Meals on Training Days

There were significant differences in the reported absolute and relative energy and macronutrient between meals consumed on training days ($P < 0.01$ for all examined absolute and relative energy intake variables; see Figure 1). Specifically, players consumed higher absolute and relative EI at dinner compared with breakfast, morning, afternoon and evening snacks ($P < 0.01$ for all comparisons). Additionally, absolute and relative EI was also greater at lunch compared with the morning and evening snacks ($P < 0.01$). Absolute and relative CHO intakes were higher at dinner compared with morning snack (both $P < 0.01$), lunch (both $P < 0.05$) and evening snack (both $P < 0.01$), with relative CHO intake also being higher at dinner compared with breakfast ($P = 0.04$).

Protein and relative protein intakes were greater at dinner compared with breakfast, morning snacks, afternoon snacks and evening snacks ($P < 0.01$ for all comparisons). In addition, absolute and relative protein intakes were greater at lunch compared with breakfast, morning snacks and evening snacks ($P < 0.01$ for all comparisons). Both absolute and

relative protein intakes were also higher at breakfast compared with evening snack (both $P < 0.02$) and higher at the afternoon snack compared with the evening snack (both $P < 0.01$).

In relation to fat intake, both absolute and relative intakes were higher at dinner compared with the morning, afternoon snacks and evening snacks ($P < 0.05$ for all comparisons). Additionally, fat intake was also higher at lunch compared with the morning snack ($P < 0.01$ for both absolute and relative intakes).

Energy and Macronutrient Intake Across Meals on Match Days

There was no significant difference ($P > 0.05$ for all meals; see Figure 2) in absolute and relative energy and macronutrient intake between meals on the two difference match days. However, significant differences were observed between meals consumed on match days for all energy and macronutrient variables (all $P < 0.05$; see Figure 2). The absolute and relative energy and protein intake were higher in the PMM and PM compared with the PMS, DM and PMRM (all $P < 0.05$). Additionally, the absolute and relative CHO intake were also higher in the PMM and PM compared with the PMS and DM (all $P < 0.05$). Fat intake in the PMM and the PM, when expressed in both absolute and relative terms, were higher than

the PMS and DM (all $P < 0.05$), where the PMM was also lower than the PMRM (both $P < 0.05$).

Discussion

Having previously quantified the daily “total” energy intake and expenditure of the players studied here (Anderson et al., 2017), the aim of the present study was to subsequently quantify the daily distribution of energy and macronutrient intakes on both training and match days. Importantly, we observed that players adopt a skewed approach to feeding on training days such that absolute energy intake, CHO and protein intake are consumed in a hierarchical manner of dinner>lunch>breakfast>snacks. Moreover, we also observed that players tend to under-consume CHO on match days in relation to pre-match and post-match meals, especially in recovery from an evening kick-off time. Taken together, our data highlight the importance of obtaining dietary data related to distribution (as opposed to total daily energy intake per se, Anderson et al., 2017) given the implications related to components of training adaptation, performance and recovery.

In our companion paper (Anderson et al., 2017), we reported that the players studied herein practiced elements of CHO periodization such that total daily CHO intake was greater on match days (i.e. $6.4 \text{ g.kg}^{-1} \text{ BM}$) compared with

324 training days (i.e. $4.2 \text{ g.kg}^{-1} \text{ BM}$). Although such CHO
325 periodization strategies may be in accordance with the principle
326 of “fuel for the work required” (Impey et al. 2016; Bartlett et
327 al., 2015; Hawley & Morton, 2015), we suggested that players
328 were likely under-consuming CHO in terms of maximizing
329 match day physical performance and recovery. Further
330 evidence highlighting this potential “sub-optimal CHO intake”
331 is also provided by the dietary distribution data provided here.
332 For example, in relation to match day itself, our data suggest
333 that players did not meet current CHO guidelines for which to
334 optimize aspects of physical (Burke et al., 2011), technical (Ali
335 & Williams, 2009) and cognitive (Welsh et al., 2002)
336 performance. Indeed, both the pre-match meal ($< 1.5 \text{ g.kg}^{-1}$
337 body mass) and CHO feeding during match play ($\sim 30 \text{ g.h}^{-1}$;
338 four players consumed $< 30 \text{ g.h}^{-1}$, see Anderson et al. 2017)
339 could be considered sub-optimal in relation to those studies
340 (Wee et al., 2005; Foskett et al., 2008) demonstrating higher
341 CHO intakes (e.g. $2\text{--}3 \text{ g.kg}^{-1}$ body mass and 60 g.h^{-1} ,
342 respectively) induce physiological benefits that are facilitative
343 of improved high-intensity intermittent performance e.g. high
344 pre-exercise glycogen stores, maintenance of plasma
345 glucose/CHO oxidation during exercise and muscle glycogen
346 sparing.
347

348 Given that the present study was conducted during a
349 two game per week schedule, there was the obvious nutritional
350 requirement to maximize muscle glycogen storage in the 24-48
351 h after each game (Krustrup et al., 2006; Bassau et al., 2002).
352 To this end, we also observed CHO intakes that would be
353 considered sub-optimal in relation to maximizing rates of post-
354 match muscle glycogen re-synthesis (Jentjens & Jeukendrup,
355 2003). Indeed, in contrast to the well-accepted guidelines of
356 1.2 g.kg⁻¹ body mass for several hours post-exercise, we
357 observed reported intakes of <1 g.kg⁻¹ in the immediate period
358 after match day 1 (i.e. the night-time kick off). Such post-game
359 intakes coupled with the relatively low absolute daily intake
360 (i.e. 4 g.kg⁻¹) on the subsequent day (see Anderson et al., 2017)
361 would inevitably ensue that absolute muscle glycogen re-
362 synthesis was likely compromised, an effect that may be
363 especially prevalent in type II fibres (Gunnarsson et al., 2013).
364 It is noteworthy, however, that the high absolute protein intakes
365 consumed in the post-match period (i.e. >50 g) would likely
366 potentiate rates of muscle glycogen re-synthesis when
367 consumed in the presence of sub-optimal CHO availability
368 (Van Loon et al., 2000).

369 Despite our observation of CHO periodization during
370 the weekly microcycle, we previously observed (Anderson et
371 al., 2017) consistent daily protein intakes (approximately 200 g
372 per day), the magnitude of which was higher than that typically

373 reported (<150 g/day) previously for adult (Maughan, 1997;
374 Bettonviel et al., 2016) and youth professional male soccer
375 players (Naughton et al., 2016). Similar to CHO intake,
376 however, it is also prudent to consider the daily distribution of
377 protein feeding given that both that skewed and sub-optimal
378 intakes at specific meal times can reduce rates of muscle
379 protein synthesis (Areta et al., 2013; Mamerow et al., 2014).
380 Indeed, recent data suggest that the timing and even
381 distribution of daily protein doses may have a more influential
382 role in modulating muscle protein synthesis when compared
383 with the absolute dose of protein intake, an effect that is
384 evident in response to both feeding alone (Mamerow et al.,
385 2014) and post-exercise feeding (Areta et al., 2013). In this
386 regard, we observed a skewed pattern of daily protein intake in
387 that absolute protein was consumed in a hierarchical order
388 where dinner>lunch>breakfast>snacks. This finding also
389 agrees with our previous observations on the protein feeding
390 patterns of elite youth soccer players (Naughton et al., 2016) as
391 well as adult players from the Dutch league (Bettonviel et al.,
392 2016) and a mixed sex cohort of Dutch athletes (Gillen et al.
393 2016). Nonetheless, given that we observed higher daily
394 protein intakes (>200 g/day) compared with the previous
395 studies (typically <150 g/day), examination of daily
396 distribution data also allows us to comment on those meals that
397 led to greater absolute protein intake. In this regard, it appears

398 that an additional absolute intake of approximately 20-25 g at
399 both lunch and dinner accounted for the greater absolute total
400 daily intake.

401 Based on recent data suggesting that trained athletes
402 (especially those with higher lean mass) may require protein
403 doses of approximately 40 g (MacNaughton et al., 2016) as
404 well as the importance of protein feeding prior to sleep (Res et
405 al., 2012), our data suggest that breakfast and morning,
406 afternoon and bedtime snacks are key times to improve for the
407 present sample. We acknowledge, however, that protein
408 requirements (both in absolute dosing and timing) should be
409 tailored to the specific population in question in accordance
410 with timing of training sessions, training load and moreover,
411 individualized training goals.

412 Despite the novelty and practical application of the
413 current study, our data are not without limitations, largely a
414 reflection of the practical demands of data collection in an elite
415 football setting. Firstly, this study is reflective of only six
416 players from one team only (albeit reflective of a top EPL
417 team) and hence may not be representative of the customary
418 training and nutritional habits of other teams. Nonetheless, we
419 deliberately recruited players with different playing positions in
420 an attempt to provide a more representative sample of
421 professional soccer players. Secondly, our deliberate choice to
422 study a two game week scenario (as is highly relevant for elite

level players) may not be applicable to players of lower standards. Thirdly, as with all dietary analysis studies, our data may be limited by both under-reporting and inter-researcher variability in ability to assess dietary intakes. Indeed, whilst we observed no significant group mean changes in body mass over the data collection period, two of our subjects did appear to under report whereas four of the subjects reported energy intake data that was comparable (within 200 kcal) to energy expenditure data (see Anderson et al. 2017). Finally, both of the games studied here represented home games and hence the nutritional choices are likely to be influenced by the philosophy and service provision of the club coaching and catering staff.

In summary, we simultaneously quantified for the first time the daily distribution of energy and macronutrient intakes of EPL soccer players on both training and match days. Our data suggest that players may benefit from consuming greater amounts of CHO in both the pre-match and post-match meals so as to increase CHO availability and maximize rates of muscle glycogen re-synthesis, respectively. Furthermore, we also observed that daily protein intake was consumed in a hierarchical manner such that dinner > lunch > breakfast > snacks. Attention should also be given to therefore ensuring even distribution of daily protein intake so as to potentially promote components of training adaptation.

447

448

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455

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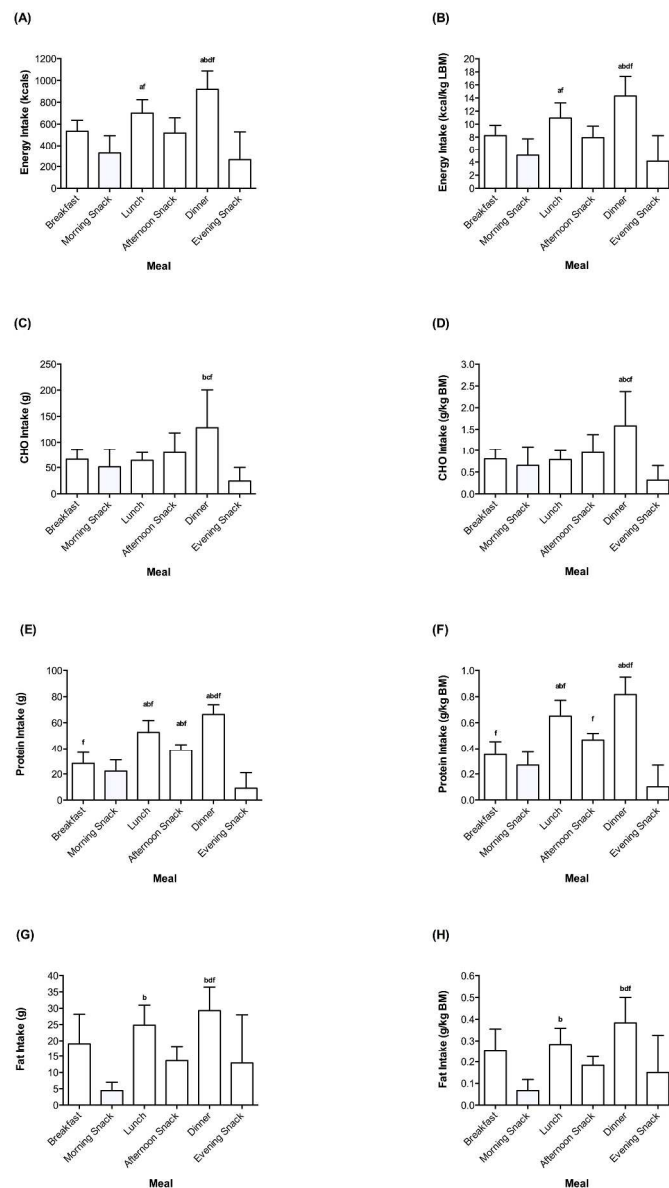


Figure 1. Energy and macronutrient intakes meal distribution on training days. Figure A=absolute energy expenditure, Figure B=energy expenditure relative to lean body mass, Figure C=absolute carbohydrate, Figure D=relative carbohydrate, Figure E=absolute protein, Figure F=relative protein, Figure G=absolute fat and Figure H=relative fat. White bars=training days and black bars=match days. a denotes difference from breakfast, b denotes difference from morning snack, c denotes difference from lunch, d denotes difference from afternoon snack, e denotes difference from dinner, f denotes difference from evening snack.

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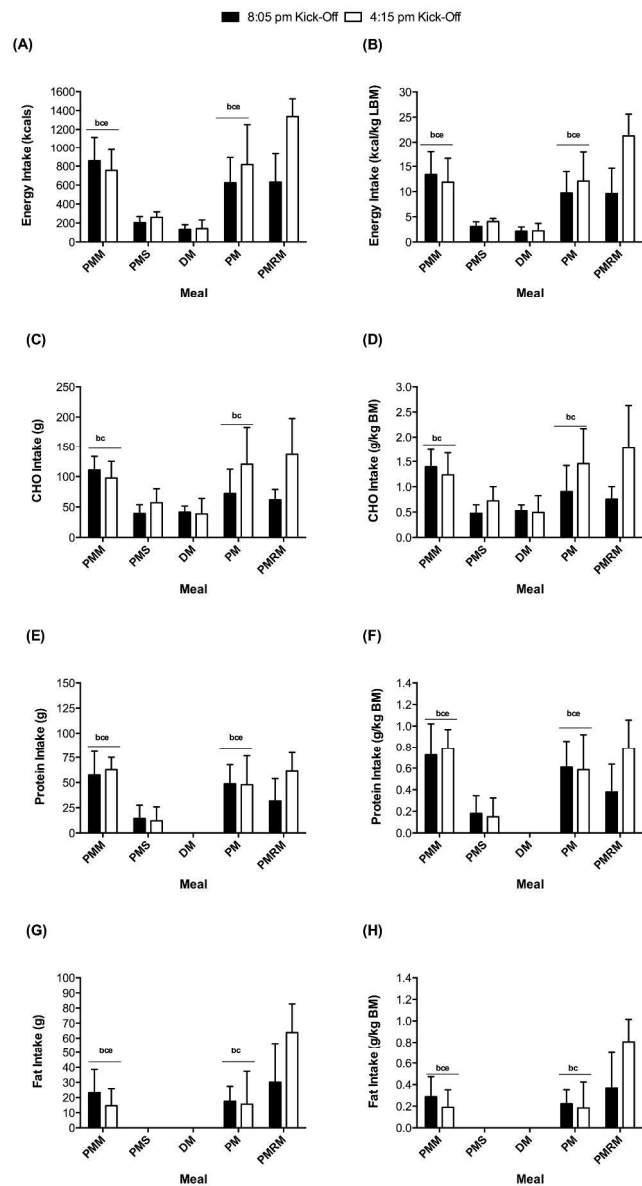


Figure 2. Energy and macronutrient intake meal distribution on the two match days during the study period. Black bars=match day 1 and white bars=match day 2. a denotes difference from PMM, b denotes difference from PMS, c denotes difference from DM, d denotes difference from PM, e denotes difference from PMRM. PMM=Pre Match Meal, PMS=Pre-Match Snack, DM=During-Match, PM=Post-Match, PMRM=Post-Match Recovery Meal.

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